EMERGENCE AND INITIAL DEVELOPMENT OF MURICI SEEDLINGS UNDER DIFFERENT SUBSTRATES

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ABSTRACT

The genus Byrsonima Rich. (MALPIGHIACEAE), whose species are popularly known as "murici" constitutes a complex of about 150 species, of which 95 can be found in Brazil, and have potential for cultivation in view of their multiple possibilities of use in timber, food and pharmaceutical industries. Despite constituting a complex of species, they are rarely cultivated. The objective of this work was to evaluate of the type of substrate on the germination and initial development of murici seedlings. The experimental treatments used seven types of substrates (T_0: commercial substrate (control treatment); T_1: commercial substrate + washed coarse sand (1: 1); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1). The experiment was carried out in a greenhouse, under a complete randomized block design, with four replicates and three plants per plot. The biometric variables were: percentage of emergence, plant height, number of leaves per plant^{-1} and the neck diameter at 80, 95, 125, 155, 185, 215, 245 and 275 days after sowing (DAS). At 275 DAS, destructive analysis was performed to determine the fresh and dry biomass of shoot and roots and the length of the largest root. The percentage of emergence, height and diameter of plants did not differ between treatments. The lowest values of fresh and dry biomass of the roots occurred in the exclusive presence of commercial substrate and in mixtures containing incorporation of bovine manure. Substrates composed of: soil, carbonized rice husk, commercial substrate and washed coarse sand, favor the daily growth rates of shoot and the development of the root system of murici seedlings. The transplanting of seedlings to the field at 200 DAS may help to maintain a larger amount of leaves in the seedlings.

Keywords: *Byrsonima verbascifolia* (L.) Rich; Cerrado; native fruit; seed; germination.

EMERGÊNCIA E DESENVOLVIMENTO INICIAL DE MUDAS DE MURICI EM DIFERENTES SUBSTRATOS

RESUMO

O gênero Byrsonima Rich. (MALPIGHIACEAE), cujas espécies são popularmente conhecidas como "murici" constituem um complexo de cerca de 150 espécies, das quais 95 podem ser encontradas no Brasil, e apresentam potencial para cultivo tendo em vista suas múltiplas possibilidades de uso nas indústrias madeireira, alimentícia e farmacêutica. Apesar de constituir um complexo de espécies, raramente são cultivadas. O objetivo deste trabalho foi avaliar o tipo de substrato na germinação e desenvolvimento inicial de mudas de murici. Os tratamentos experimentais utilizaram sete tipos de substratos (T_0: substrato comercial (tratamento controle); T_1: substrato comercial + areia grossa lavada (1:1); T_2: esterco bovino + substrato comercial + terra (1:1:3); T_3 : esterco bovino + terra (2: 3); T_4: casca de arroz carbonizada + substrato comercial + terra (1: 1: 3); T_5: substrato comercial + areia + terra (1: 1: 1); T_6: areia grossa lavada + solo (1:1). O experimento foi conduzido em casa de vegetação, em delineamento de blocos ao acaso, com quatro repetições e três plantas por parcela. As variáveis biométricas foram:

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porcentagem de emergência, altura da planta, número de folhas por planta^{-1} e diâmetro do colo aos 80, 95, 125, 155, 185, 215, 245 e 275 dias após a semeadura (DAS). Aos 275 DAS foi realizada análise destrutiva para determinação da biomassa fresca e seca da parte aérea e das raízes e o comprimento da maior raiz. A porcentagem de emergência, altura e diâmetro das plantas não diferiram entre os tratamentos. Os menores valores de biomassa fresca e seca das raízes ocorreram na presença exclusiva de substrato comercial e em misturas contendo incorporação de esterco bovino. Substratos compostos por: solo, casca de arroz carbonizada, substrato comercial e areia grossa lavada, favorecem as taxas de crescimento diário da parte aérea e o desenvolvimento do sistema radicular do murici mudas. O transplante das mudas para o campo aos 200 DAS pode ajudar a manter maior quantidade de folhas nas mudas.
Palavras-chaves: *Byrsonima verbascifolia* (L.) Rich; Cerrado; fruta nativa; sementes; germinação.

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INTRODUCTION

Murici (*Byrsonima* spp., Malpighiaceae) is described as a hermaphrodite tree or shrub, measuring 4 m to 6 m, its trunk is often tortuous (Vieira et al., 2010; Almeida et al., 2016), planting must be carried out by seeds and, rarely, by seedlings (Murakami et al., 2011). The fruits are edible and highly appreciated by local populations and wild animals, and can be consumed in natura or sold as pulps, juices, sweets, ice cream and liqueurs (Almeida et al., 2016; Araújo, 2009; Souza et al., 2020). The propagation of the genus *Byrsonima* occurs through seeds with 0.5 cm in diameter (Garritano et al., 2006; Peixoto et al., 2011), contained in the pyrenees. Pyrene is formed by a set of resistant stony endocarp and seeds, which varies from one to three, since the ovary of the flower is triloculated, and each locule is uniovulated. Therefore, the presence of sclerified endosperm that surrounds the embryo, acts as a mechanical barrier, which causes low and uneven germination rate, with slow seedling emergence (Vasconcelos Filho, 2008; Assis et al., 2017). This fact has already been verified for the species: *Byrsonima verbascifolia* (Assis et al., 2017; Carvalho; Nascimento, 2008), *B. cydoniifolia* A. Juss. (Araújo, 2009), *B. coccolobifolia*, *B. lancifolia*, *B. sericea*, *B. spicata*, *B. stipulacea* (Lorenzi, 2002; Donadio et al., 2004; Nogueira et al., 2004; Carvalho et al., 2007).

Alternatively, "bare" seeds, that is, devoid of the endocarp, are not used as a propagation structure due to the difficulty of removing them from the inside of this structure, in addition to the fact that it is easily damaged when it is removed (Assis et al., 2017; Carvalho & Nascimento, 2008). Faced with the challenge of seed propagation, the substrate has the purpose of providing support to seedlings, both from the physical point of view, as well as chemical and biological (Schafer; Lerner, 2022).

The substrate must be easily available for purchase and transport, free of pathogens and weeds, rich in essential nutrients, presenting an appropriate pH for the species that is multiplying, and have a good texture and structure (Schafer; Lerner, 2022; Prisa, 2023). The characteristics of structure, aeration, water retention capacity and degree of decontamination by pathogens, among others, vary according to the material used in the composition of the substrate, which may affect the germination and seedling establishment and consequently influence the final quality of the seedlings (Silva et al., 2011, Kaushal; Kumari, 2020).

The substrate can be characterized by having a pure form or mixture capable of allowing the development of the root system, considered as support for the plant (Prisa, 2023)). However, a material alone will not always have all the desirable characteristics for the formation of seedlings. With that, it becomes feasible to mix two or more materials to obtain a suitable substrate for a given species (Biasi et al., 1995). The quality of the substrate also depends on the proportions and the materials that make up the mixture (Dias et al., 2010, Schafer; Lerner, 2022).

In this context, the objective was to evaluate the influence of diferent substrates on the germination and initial development of seedlings of *Byrsonima verbascifolia* (L.) Rich. in order to contribute with subsidies for the production of seedlings and cultivation of the species.

MATERIAL AND METHODS

The experiment was carried out in the greenhouse of the experimental area of the Federal Institute of Goiás, Campus Ceres, GO (5° 21'0.84 "S and 49° 35'55.40" W). The seeds used came from ripe, healthy and fallen fruits in the soil by the process of natural abscission, from genotypes of the collection of native fruits of the Cerrado of the same institution.

The fruits were manually pulped, as this method favors less mechanical damage to the embryo, guaranteeing the physiological quality of the seed (Barros, 2006). Subsequently, the seeds (pyrenees) were washed in running water until complete removal of the mucilage, eliminating the possible germination inhibiting substances present in the pulp. Due to their low germination rate (3%) and slow seedling emergence (Vieira et al., 2010), the pyrenes were subjected for 24 hours to a dormancy break in a solution of gibberellic acid (GA_3) at a concentration of 2 g L^{-1}.

Sowing was carried out in black polyethylene bags measuring 30 cm x 12 cm, using four seeds per container, inserted 1.5 cm deep on substrates made up of different mixtures: (T0: commercial substrate (control treatment), formulated with organic compost, pine bark, vermiculite and NPK; T_1: commercial substrate + washed coarse sand (1: 1)); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1). The proposition of the mixtures mentioned above was based on work carried out with Cerrado species such as Sobrinho et al. (2010) and Pinheiro et al. (2020).

For the evaluation of germination and emergence, the treatments were arranged in a randomized complete block test, with 10 sachets per treatment (total of 70 plots) and three seeds sown per sachet, repeated in four blocks (total of 280 plots and 840 sown seeds). The containers (plastic bags) remained in the greenhouse with an intermittent nebulization system, with intervals of 60 minutes every one minute of operation and weekly weeding of spontaneous plants. The emergence of the plants was monitored daily and when it reached stabilization, 80 days after sowing (DAS), the mean time and the percentage of emergence were determined. Seedlings with totally free and normal cotyledons were considered emerged.

The initial development of murici was evaluated from 80 DAS, that is, after the stabilization of the emergency. For this, the emerged seedlings were transplanted, in order to leave only one plant per container, keeping the treatments in a complete randomized block design, with four replicates. The following biometrics variables were evaluated: plant height (with the aid of a ruler graduated in centimeters, measuring the distance between the neck and the apex of the shoot), number of leaves per plant^{-1} and the diameter of the neck (with digital caliper) in millimeters at 80, 95, 125, 155, 185, 215, 245 and 275 DAS. At 275 DAS, a destructive analysis of each treatment was performed to determine the fresh and dry biomass of the shoot and the roots and the length of the largest root. The shoot and the root system of three seedlings of each treatment were dried in a forced circulation oven at 60ºC, until reaching constant weight obtained in 72 hours, according to the methodology of Hunter (Hunter, 1974), for later determination of the weight value the dry matter of the shoot and the root system.

The daily growth rates (DGR) of height, diameter and number of leaflets, except for the rate at 95 DAS, were calculated by varying the values of each variable every 30 days. Biometric data, since they do not present normal residues, were transformed by the expression: $Y=\sqrt{x}$. The fresh and dry biomass of the shoot and roots at 275 DAS were subjected to analysis of variance and when there was significance the means were compared using the Scott Knott test (5%). The DGR between substrates when significant were subjected to regression to determine growth trends over time. All statistical analyzes were performed with the aid of software R version 3.2.2 (R Core Team, 2015).

RESULTS AND DISCUSSION

There was no significant difference between the treatments evaluated for the variable percentage of seedling emergence and time of emergence of murici seedlings, possibly due to the low emergence rate of treatments (Table 1). Others *Byrsonima* species had been observed to has a low germination rate and slow emergence, such as *B. coccolobifolia*, *B. lancifolia* and *B. sericea* (Lorenzi, 2002); also, in *B. cydoniifolia* (Murakami et al., 2011) and *B. crassifolia* (Carvalho; Nascimento, 2008).

Table 1. Average, minimum, maximum and coefficients of phenotypic variation (CV%) of the percentage of emergence (PE) and time of emergence (TE) of murici seedlings according to different substrates.

Treatment	**PE (%)**	**TE (days)**
T0*	17.50	44
T1	8.750	35
T2	8.750	37
T3	9.370	43
T4	18.13	39
T5	15.00	43
T6	13.13	38
Average	12.90	40
Minimum	0.000	28
Maximum	100.0	69
CV%	201.0	24.34

*T_0: commercial substrate (control treatment); T_1: commercial substrate + washed coarse sand (1: 1); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1).

The average percentage of emergency (PE) presented by murici, 12.90%, is low when compared to the average value found for other fruit native to the Cerrado, such as baru (*Dipteryx alata* Vog., Fabaceae) (93.80%) (Mota, 2013), cagaita (*Eugenia dysenterica* DC., Myrtaceae) (82.03%) (Novaes, 2014) and mangabeira (*Hancornia speciosa* Gomes, Apocynaceae) (~53.13%) (Pinheiro et al., 2020), regardless of the type of substrate used (Silva et al., 2009). The low variation in the emergence of murici seedlings in relation to different substrate formulations suggests that the germinative behavior of this species is more related to intrinsic factors of the genotype, which determines the chemical composition of the seed reserves, recalcitrance and / or even dormancy than with the chemical or physical composition of the substrate used to produce seedlings. This can be observed when analyzing the CV of the experiment, above 200%, reinforcing the above reasoning about intraspecific variability, since the seeds were collected in different matrices.

The types of substrates did not influence ($p > 0.05$) the final height (FH) and diameter (FD), while the final number of leaflets per plant (NOLFP) was influenced by the type of substrate used ($p < 0.05$) (Table 2).

Table 2. Analysis of variance and mean (between plants) of the variables (initial height (IH), final height (FH), initial diameter (ID), final diameter (FD), number of leaflets per initial plant

(NOLIP) and number of leaflets per final plant (NOLFP)) of murici seedlings according to different substrates. The initial assessments were carried out at 80 and the final at 275 DAS.

SV	DF	MEAN SQUARE					
		IH	FH	ID	FD	NOLIP	NOLFP
Treatments	6	0.1768 NS	3.040 NS	0.017 NS	2.1985 NS	0.2573 NS	4.0718 *
Block	3	0.1504 NS	6.695 **	0.010 NS	1.1769 NS	0.1319 NS	0.8578 NS
Residue	74	0.0963	1.421	0.019	1.2142	0.2009	1.6407
CV (%)		16.41	23.27	14.38	51.66	18.01	25.07

NS= not significant; * significant at 5% probability and ** significant at 1% probability. SV: Source variation; DF: degrees of freedom.

The number of leaflets per plant (NOLFP) at 275 days after sowing (DAS) was influenced by the type of substrate (Figure 1). The mixtures containing washed coarse sand were superior (T_1 and T_6), due to the sand's capacity to increase the porosity of the substrates, which allows greater water drainage capacity, keeping the substrate with less humidity (Romano et al., 2022). For many species, sand has been used purely in the seed germination phase, with seedlings subsequently transplanted to substrates that provide ideal conditions, such as nutrients and stability for seedling growth and development, allowing an increase in biomass of shoot and root (Romano et al., 2022).

In jatobá (*Hymeneae courbaril* L. var. Stilbocarpa, Fabaceae) seedlings, mixtures containing sand in its formulation provided increased aeration, decreased resistance of the root system to penetrate the substrate and greater vegetative growth of the seedling, consequently resulting in taller plants (Cabral et al., 2015). In another species of murici, *B. cydniifolia*, the sand allows a great variation in temperature to occur, thus, by irrigating this substrate, it facilitates the occurrence of thermal shock, which favors the rupture of the endocarp for germination (Santos et al., 2011).

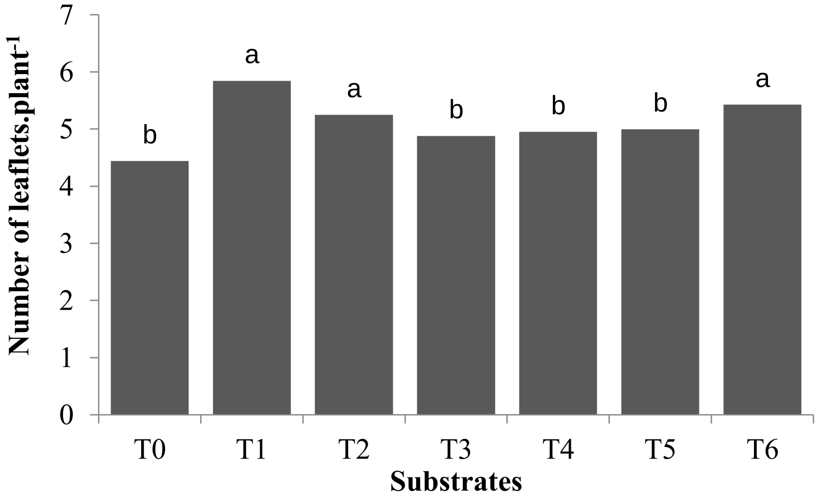

Figure 1. Number of per leaflets per murici plant as a function of different substrate compositions at 275 DAS of *Byrsonima verbascifolia*. T_0: commercial substrate (control treatment); T_1: commercial substrate + washed coarse sand (1: 1); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1). *Equal letters do not differ by the Scott-Knott test at 5% probability.

The length of the largest root, fresh biomass and dry biomass were influenced by the type of substrate. The growth of the largest root was limited in mixtures containing bovine manure in its composition (T2 and T3), consequently reducing to fresh and dry biomass compared to other substrate compositions (Figures 2 and 3). Similar results were observed in species that are also native to the cerrado in jatobazeiro and in mangabeira, barueiro and cagaiteira, in which the addition of organic matter (bovine manure and chicken litter) in the substrate impaired the performance of the aerial part and the roots of the seedlings (Sobrinho et al., 2010).

This fact indicates that the murici species, being native to poor soils, does not respond to the increase in organic matter in the substrate, as it possibly has mechanisms that allow it to tolerate nutritional limitations, a characteristic present in Cerrado soils. Schafer (2022) suggests that animal manure should be used as complementary chemicals in a substrate given the higher concentration of salts in this type of compound. There is a low response of some Cerrado species to the increase in substrate fertility, and this increase in fertility may even be detrimental to the development of the seedling (Melo et al., 1998; Massi, 2015).

Figure 2. Length of the largest root at 275 DAS as a function of different substrate compositions of *Byrsonima verbascifolia*. T_0: commercial substrate (control treatment); T_1: commercial substrate + washed coarse sand (1: 1); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1).

The lowest values of fresh and dry biomass of the roots occurred in the exclusive presence of commercial substrate and in mixtures containing incorporation of bovine manure (Figure 3; T_0, T_2 and T_3). The presence of bovine manure may have increased the amounts of nitrogen (N) and phosphorus (P) in relation to the other essential nutrients in plants, causing nutritional imbalance thus influencing root growth. Whereas the exclusive presence of commercial substrate, which is quite porous, may have accelerated the infiltration of water, consequently affecting the transpiration of the roots.

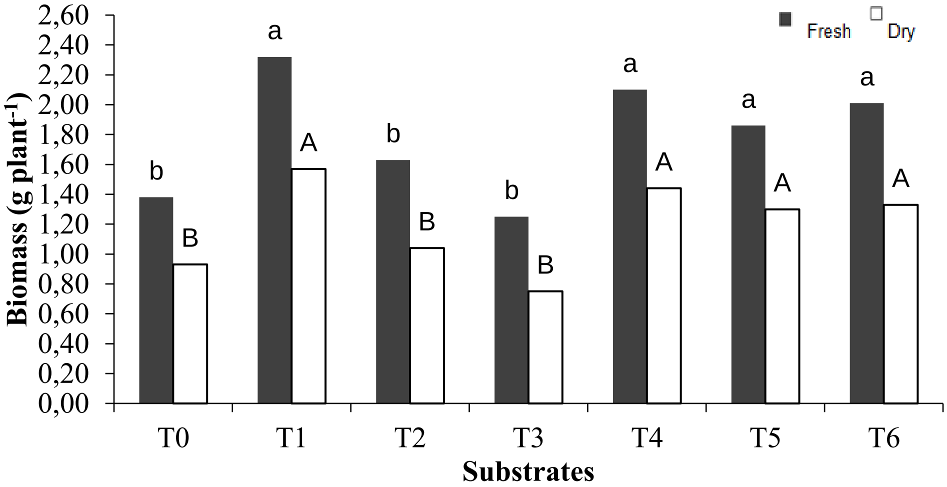

Figure 3. Fresh and dry biomass of murici seedling roots as a function of different substrate compositions at 275 DAS. T_0: commercial substrate (control treatment); T_1: commercial substrate + washed coarse sand (1: 1); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1). *Lower case letters compare fresh biomass and upper case letters compare dry biomass.

The lower development of mangaba, cagaita and baru seedlings can occur when there is an increase in the concentration of phosphorus, caused by the use of manure, a source rich in nitrogen and organic matter (Sobrinho et al., 2010). This is because phosphorus, in addition to being an element required in large quantities for the production of seedlings, sometimes even more than nitrogen itself, when in high quantities and in combination with organic substrates, reduces plant growth (Raij, 1991). The composition of the substrate, especially in relation to the balance of nutrients necessary for the seedlings to develop satisfactorily, is essential, as it is what allows desirable results to be obtained in the main parameters that determine the quality of the seedling (Ceconi et al., 2007).

The daily growth rate (DGR) in height was influenced by the type of substrate as well as by the time the seedlings remained in the packages (Figure 4). The DGR of the leaflets was influenced only by the length of stay.

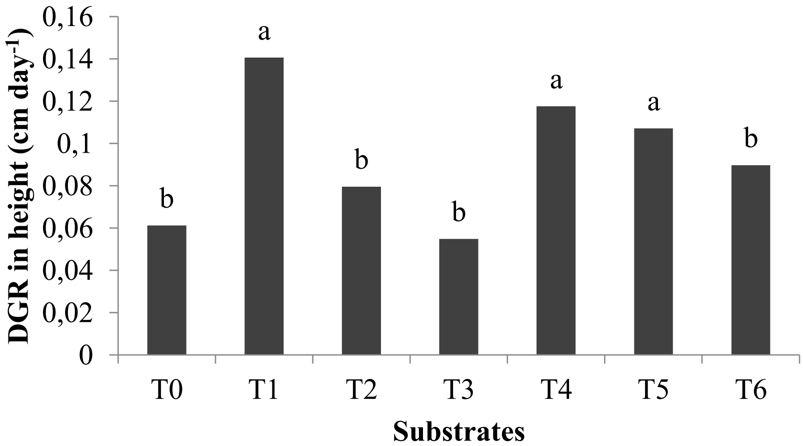

Figure 4. Rate of daily height growth (DGR in height) of murici seedlings (*Byrsonima verbascifolia*) as a function of different substrate compositions. T_0: commercial substrate (control treatment); T_1: commercial substrate + washed coarse sand (1: 1); T_2: cattle manure + commercial substrate + soil (1: 1: 3); T_3: cattle manure + soil (2: 3); T_4: carbonized rice husk + commercial substrate + soil (1: 1: 3); T_5: commercial substrate + sand + soil (1: 1: 1); T_6: coarse washed sand + soil (1: 1). * Equal letters do not differ by the Scott-Knott test at 5% probability.

The highest DGR of the height were observed in the treatments in which there was a combination of commercial substrate with carbonized rice husk, washed coarse sand and soil. In treatments where there was an excessive presence of commercial substrate and/or incorporation of bovine manure, there was less development of the root system, which may have compromised the DGR of the height of murici seedlings (Figure 4).

The roots are directly linked to the development of the plant, since they are responsible for the absorption of water and nutrients from the soil and their subsequent translocation to the aerial part. In addition, they are responsible for the synthesis of hormonal molecules and enzymatic co-factors linked to the processes of cell expansion and division, thus affecting plant growth and development (Taiz; Zeiger, 2003).

In this study, there was a progressive growth of the aerial part of murici seedlings as a function of time (Figure 5), whose average growth rate was around 0.0910 cm day^{-1}. However, this growth, although it was progressive, allowed the plants an average height of only 27.43 cm at 275 DAS, which characterizes the species as being of slow growth. In native Savannah plants, the initial growth of seedlings is slow due to the genetic characteristics (slow cell division and differentiation) that are particular to each species and evolutionary, by which most native species of the Cerrado were subjected as: low soil fertility and water limitation (Sano; Almeida, 1998). The cagaiteira and murici-pequeno (*Byrsonima intermedia*), respectively, are also species that show slow initial vegetative growth (Souza, 2000; Silva, 2010).

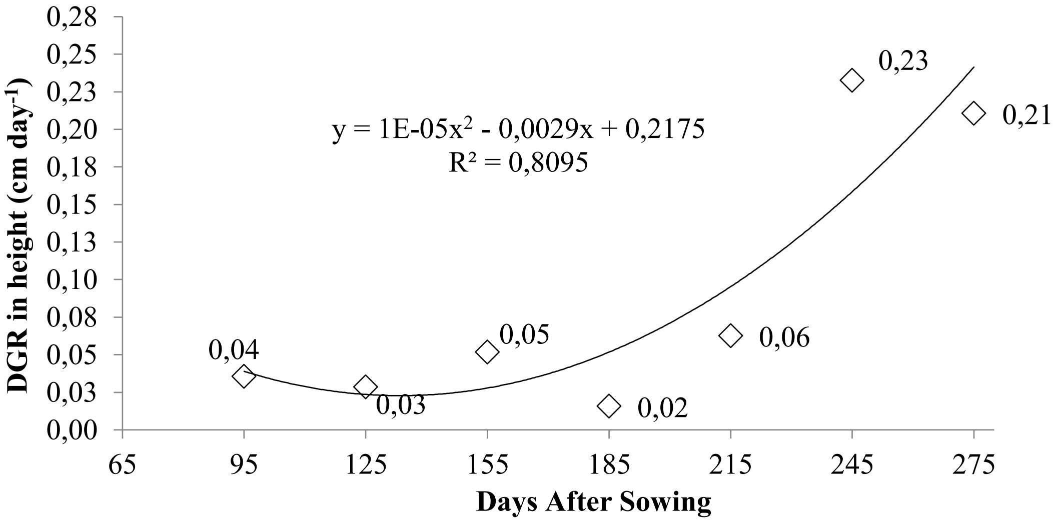

Figure 5. Growth of murici seedlings as a function of different substrate compositions (combination of commercial substrate with carbonized rice husk, washed coarse sand and soil) over the days after sowing.

This slow initial growth occurs because the Cerrado plants spend a large part of the energy for fixation in the soil exclusively, with the exploitation of it for the emission of roots by the plant, being the roots in this phase the preferential drain of the photoassimilates, leading to the greater production of root dry matter when compared to the aerial part (Santos et al., 2018).

It was observed that even with an progressive growth (Figure 5), over time, murici plants were affected in terms of leaf emission, which from an agronomic point of view is not desirable (Figure 6).

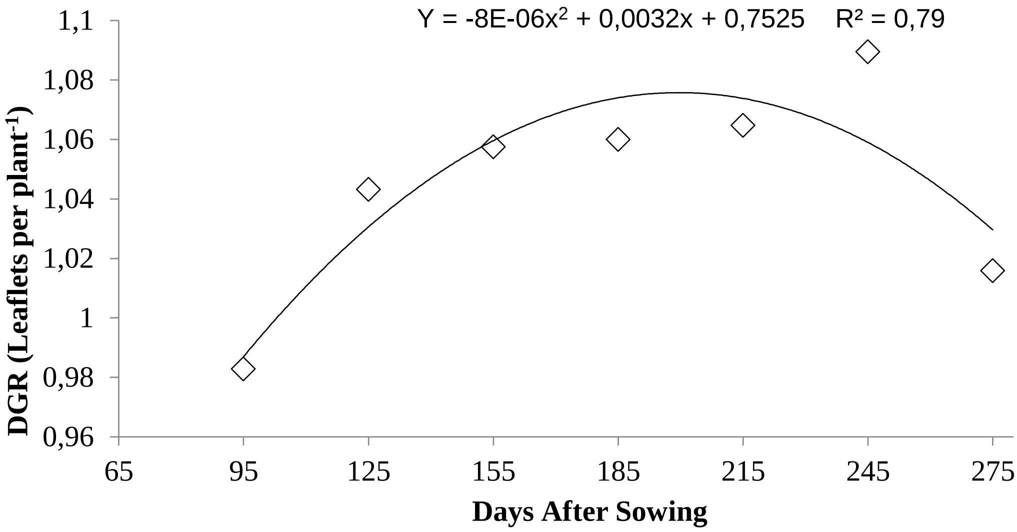

Figure 6. Rate of daily growth of leaflets (DGR Leaflets per plant^{-1}) as a function of different compositions (combination of commercial substrate with carbonized rice husk, washed coarse sand and soil) of murici seedling substrate.

Deriving the adjustment equation to the DGR data of leaflets, it was observed that from 200 DAS there was a reduction in the DGR of the number of plant^{-1} leaflets. The volume of the containers (approximately 2 kg of substrate) may have caused physical limitation to promote root growth (Schafer; Lerner, 2022). Souza (2000) and Santos et al. (2018) found a smaller stem diameter in cagateira seedlings at 160 DAS than at 60 DAS and mangabeira at 210 DAS than at 120 DAS, respectively, and attributed this to the use of nutritional reserves for plant recovery, after the stress suffered around 90 DAS.

The 200 DAS period can be considered the critical moment for transplanting the seedlings to the field, since they already present physical conditions (height of ± 8.95 cm and diameter of ± 2.7 mm) capable of allowing their development, provided that fortnightly irrigation is carried out for survival or that water is supplied, meeting the water needs of the plant, considerably reducing the time for seedling formation. Souza (2000) and Santos et al. (2018) states that because some tree species in the Cerrado have greater growth of the root system in relation to the shoot it is desirable to produce seedlings in larger packages, or else the transplant should occur earlier, when the plants are younger.

Leaf loss after 200 DAS presents itself more as a possible strategy for the survival of the seedlings in response to the physical limitations of the container, than as a response to the nutritional deficiency of the substrates used, since gains in height of aerial part, length and root biomass were verified in the different substrate compositions.

CONCLUSION

Murici germination is low and does not depend on the type of substrate used.

The exclusive use of commercial substrate and the incorporation of bovine manure, regardless of the proportion, limit the development of the root system of murici seedlings.

Substrates containing in its formulation mixtures of: soil, carbonized rice husk, commercial substrate and washed coarse sand, favor the daily growth rates of the shoot and the development of the root system of murici seedlings.

The period of 200 days after sowing is the ideal time for transplanting seedlings to the field. From which the daily growth rate of the number of leaflets decreases regardless of the type of substrate used in the production of murici seedlings.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results

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